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⑤発明の名称　伝送システム

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明　細　書

発明の名称　伝送システム

特許請求の範囲

移動局から第1の衛星を介して固定局に測位開始信号を伝送し、

上記固定局がこの測位開始信号を受信すると、第1及び第2の基準信号を伝送し、

上記移動局が上記第1の衛星を介した上記第1の基準信号と第2の衛星を介した上記第2の基準信号とを受信し、

上記移動局で、上記測位開始信号を伝送してから上記第1の基準信号を受信するまでの時間と、上記測位開始信号を伝送してから上記第2の基準信号を受信するまでの時間とを計測し、

該計測したそれぞれの時間情報を上記移動局から上記固定局に伝送し、上記固定局で伝送される上記それぞれの時間情報に基づいて上記移動局の位置を測位するようにした伝送システム。

発明の詳細な説明

〔産業上の利用分野〕

本発明は、通信衛星を用いて移動体の測位を行う伝送システムに関する。

〔発明の概要〕

本発明は、通信衛星を用いて移動体の測位を行う伝送システムにおいて、移動体からの1個の衛星を介した1回線の固定局への伝送と、固定局からの2個の衛星を介した2回線の移動体への伝送とで、測位ができるようにし、移動体が1回線分だけの送信装置を搭載する簡単な構成で測位ができるようにしたものである。

〔従来の技術〕

従来、自動車、船舶等の移動体の位置を測位するときに、通信衛星を用いて測位することが行われている。この場合、例えば3個以上の衛星を使用すれば、それぞれの衛星からの信号を移動体で受信し、受信タイミングより得られる情報に基づいて4元の一次方程式を解くことで、移動体の位置が算出される。この測位システムは、数多くの

衛星を必要とすると共に、それに対応した数の受信装置が移動体側に必要で、さらに測位のための正確な演算を移動体側で行う必要があった。

これに対し、2個の静止衛星だけを使用すると共に、地上の固定局で測位のための演算を行うようにした移動体の位置測位システムが、特開昭61-48781号公報等に記載されているように提案されている。

この位置測位システムは、ジオスターシステム等と称され、例えば第3図に示す伝送システムにより測位が行われる。即ち、トラック等の移動体(1)の現在位置を測位する場合、この移動体(1)に、第1の静止衛星(2)からの電波の受信装置と、この第1の静止衛星(2)への電波の送信装置と、第2の静止衛星(3)への電波の送信装置とを設ける。そして、地上の固定局(4)には、第1の静止衛星(2)への電波の送信装置と、第1の静止衛星(2)からの電波の受信装置と、第2の静止衛星(3)からの電波の受信装置とを設ける。また、固定局(4)とは離れた位置に位置校正用固定測定局(5)を設ける。この位置校正用固定測定局(5)は、第1の静止衛星(2)からの電波の受信装置と、この第1の静止衛星(2)への電波の送信装置と、第2の静止衛星(3)への電波の送信装置とを備える。

次に、このシステムにより測位する手順を第4図を参照して説明すると、まず固定局(4)からは、正確に時間管理された同期信号を第1の静止衛星(2)に向けて送出する。この同期信号は、測位を行うときに、第1の静止衛星(2)で中継されて、移動体(1)に搭載された受信装置により受信される。ここで、同期信号の固定局(4)から第1の静止衛星(2)への伝送に要する時間を $t_1$ とし、第1の静止衛星(2)から移動体(1)への伝送に要する時間を $t_2$ とする。

そして、移動体(1)では、この同期信号を受信してから所定時間 $t_0$ が経過すると、第1の静止衛星(2)に向けて、この移動体(1)の端末のＩＤ番号と受信信号に含まれる情報を含むパケット信号を送出する。また、同期信号を受信してから所定時間 $t_0$ が経過して、第2の静止衛星(3)に向けて、同様のパケット信号を送出する。この場合、信号を送出するまでの時間 $t_0$ は、常に一定の値とされ、固定局(4)にこの時間 $t_0$ の情報が記憶されている。ここで、移動体(1)から第1の静止衛星(2)へのパケット信号の伝送に要する時間を $t_2'$ とし、移動体(1)から第2の静止衛星(3)へのパケット信号の伝送に要する時間を $t_3$ とする。

このそれぞれのパケット信号は、第1の静止衛星(2)及び第2の静止衛星(3)で中継されて、固定局(4)で受信される。ここで、第1の静止衛星(2)から固定局(4)へのパケット信号の伝送に要する時間を $t_1'$ とし、第2の静止衛星(3)から固定局(4)へのパケット信号の伝送に要する時間を $t_4$ とする。

そして、固定局(4)では、第1の静止衛星(2)と第2の静止衛星(3)から受信したそれぞれのパケット信号の受信時刻と、固定局(4)自身が送出した同期信号の送信時刻と、固定局(4)と各静止衛星(2)及び(3)との距離から、各静止衛星(2)及び(3)と移動体(1)との距離を算出する。即ち、固定局(4)と各静止衛星(2)及び(3)との距離は、不変であるので予め固定局(4)で判断できる。このため、各静止衛星(2)及び(3)を介して行われる移動体(1)と固定局(4)との間の伝送時間 $t_1$, $t_2$, $t_1'$, $t_2'$, $t_3$, $t_4$ の内、固定局(4)と各静止衛星(2)及び(3)との間の伝送時間 $t_1$, $t_1'$, $t_4$ は距離から判断できる。この場合、時間 $t_1$ と $t_1'$ 及び時間 $t_2$ と $t_2'$ は、同一時間（距離）である。そして、残りの伝送時間 $t_2$, $t_2'$, $t_3$ は、移動体(1)の位置により変化するが、時間 $t_2$ と $t_2'$ とは同一距離の伝送なので同一時間であり、固定局(4)が同期信号を送出してから第1の静止衛星(2)からのパケット信号を受信するまでに要した時間 $t_5$ から、既知の時間 $t_1$, $t_1'$, $t_0$ を減算することで、伝送時間 $t_2$ （$t_2'$）が算出される。そして、この伝送時間 $t_2$ が判ると、固定局(4)が同期信号を送出してから第2の静止衛星(3)からのパケット信号を受信するまでに要した時間 $t_6$ から、既知の時間 $t_1$, $t_2$, $t_4$, $t_0$ を減算することで、伝送時間 $t_3$ が算出される。

このようにして伝送時間 $t_2$, $t_3$ が算出され

ると、伝送速度からこの時間情報 $t_1$, $t_2$ が距離情報に換算でき、移動体(1)と各静止衛星(2)及び(3)との距離が求まる。そして固定局(4)では、さらにこの2つの距離と各静止衛星(2)及び(3)の正確な位置情報に基づいて、移動体(1)の2次元的な位置を算出する。

そして、この算出した2次元的な位置情報と、固定局(4)が備える地勢図のデータベースを用いて、移動体(1)の3次元的な位置を算出する。

ここで、この固定局(4)での演算により移動体(1)の位置が算出される状態を、第5図を参照して説明すると、所定の静止衛星軌道上にある各静止衛星(2)及び(3)と移動体(1)との距離を、それぞれ $d_1$ 及び $d_2$ とすると、第1の静止衛星(2)から距離 $d_1$ だけ離れた地球E上の点は、円 $c_1$ を描く。また、第2の静止衛星(3)から距離 $d_2$ だけ離れた地球E上の点は、円 $c_2$ を描く。そして、この円 $c_1$ と $c_2$ との交点は、北半球と南半球とに1箇所ずつ存在し、地勢図のデータベースよりこの交点 $e_1$ の座標位置が判る。

なお、この座標位置の検出を行う場合に、各サービスエリア内に位置校正用固定局(5)を設け、固定局(4)と位置校正用固定局(5)との間で、各静止衛星(2)及び(3)を介して信号の伝送を行い、返送される信号に基づいて検出した座標位置の校正を行うようにしても良い。

〔発明が解決しようとする課題〕

ところで、この伝送システムによる移動体(1)の位置検出は、移動体側から固定局に伝送する所謂インバウンドの2回線の伝送と、固定局から移動体側に伝送する所謂アウトバウンドの1回線の伝送とが必要で、移動体(1)が、第1の静止衛星(2)への電波の送信装置と第2の静止衛星(3)への電波の送信装置との2組の送信装置を備える必要がある。この場合、静止衛星への電波の送信装置は比較的大きな送信アンテナ等の大掛かりな装置が必要で、自動車のような比較的小型の移動体に2組の送信装置を備えるのは、容易ではなかった。また、静止衛星自体も、移動体からの比較的小電力の電波を中継するものが2個必要で、システムの構成にコストがかかる不都合があった。

本発明の目的は、移動体からの1回線の送信による簡単なシステム構成により測位ができるようにすることにある。

〔課題を解決するための手段〕

本発明は、例えば第1図に示す如く、移動体(11)から第1の衛星(12)を介して固定局(14)に測位開始信号を伝送し、固定局(14)がこの測位開始信号を受信すると、第1及び第2の基準信号を伝送し、移動体(11)が第1の衛星(12)を介した第1の基準信号と第2の衛星(13)を介した第2の基準信号とを受信し、移動体(11)で、測位開始信号を伝送してから第1の基準信号を受信するまでの時間と、測位開始信号を伝送してから第2の基準信号を受信するまでの時間とを計測し、この計測したそれぞれの時間情報を移動体(11)から固定局(14)に伝送し、固定局(14)で伝送されるそれぞれの時間情報に基づいて移動体(11)の位置を測位するようにしたものである。

〔作用〕

このようにしたことで、移動体からの1個の衛星を介した1回線の固定局への伝送と、固定局からの2個の衛星を介した2回線の移動体への伝送とで測位ができ、移動体が1回線用の送信装置だけを搭載する簡単な構成で測位ができる。

〔実施例〕

以下、本発明の一実施例を、第1図及び第2図を参照して説明する。

本例においては、第1図に示す伝送システムにより測位が行われる。即ち、第1図において(11)はトラック等の測位を行う移動体を示し、この移動体(11)は、第1の静止衛星(12)からの電波の受信装置と、第2の静止衛星(13)からの電波の受信装置と、第1の静止衛星(12)への電波の送信装置とを設ける。この場合、移動体(11)から第1の静止衛星(12)への送信は、例えば 1.6 GHz帯の周波

数で行われ、各静止衛星(12)及び(13)から移動体(11)への送信は、例えば4GHz帯の周波数で行われる。そして、地上の固定局(14)には、第1の静止衛星(12)への電波の送信装置と、第2の静止衛星(13)への電波の送信装置と、第1の静止衛星(12)からの電波の受信装置とを設ける。

次に、このシステムにより測位する手順を第2図を参照して説明すると、まず移動体(11)が現在位置を測位したいときには、移動体(11)から第1の静止衛星(12)に測位開始信号を送出する。このとき、移動体(11)は測位開始信号を送出した時刻を記憶する。ここで、移動体(11)から第1の静止衛星(12)への測位開始信号の伝送に要する時間を $t_{11}$ とする。

そして、第1の静止衛星(12)により中継されたこの測位開始信号を、固定局(14)で受信させる。ここで、第1の静止衛星(12)から固定局(14)への測位開始信号の伝送に要する時間を $t_{12}$ とする。この測位開始信号を固定局(14)が受信すると、所定時間 $t_{13}$ 後に、所定の識別信号が含まれた第1の基準信号を第1の静止衛星(12)に送出する。また、測位開始信号を固定局(14)が受信してから所定時間 $t_{14}$ 後に、所定の識別信号が含まれた第2の基準信号を第2の静止衛星(13)に送出する。ここで、固定局(14)から第1の静止衛星(12)への測位開始信号の伝送に要する時間を $t_{12}'$ とし、固定局(14)から第2の静止衛星(13)への測位開始信号の伝送に要する時間を $t_{15}$ とする。

そして、第1の静止衛星(12)により中継された第1の基準信号を、移動体(11)で受信させる。また、第2の静止衛星(13)により中継された第2の基準信号を、移動体(11)で受信させる。この場合、移動体(11)では、受信した基準信号に含まれる識別信号より、どの衛星で中継された基準信号かが判別される。ここで、第1の静止衛星(12)から移動体(11)への第1の基準信号の伝送に要する時間を $t_{11}'$ とし、第2の静止衛星(13)から移動体(11)への第2の基準信号の伝送に要する時間を $t_{16}$ とする。

そして、移動体(11)では、測位開始信号を送信してから第1の静止衛星(12)からの第1の基準信号を受信するまでに要した時間 $t_a$ と、測位開始信号を送信してから第2の静止衛星(13)からの第2の基準信号を受信するまでに要した時間 $t_b$ とを計測する。

そして、移動体(11)はこの計測したそれぞれの時間 $t_a$, $t_b$ の情報を、第1の静止衛星(12)を介して固定局(14)に伝送する。そして、固定局(14)では、計測したそれぞれの時間 $t_a$, $t_b$ から各静止衛星(12)及び(13)と移動体(11)との距離を算出する。即ち、固定局(14)と各静止衛星(12)及び(13)との距離は、不変であるので予め固定局(14)で判断できる。このため、各静止衛星(12)及び(13)を介して行われる移動体(11)と固定局(14)との間の伝送時間 $t_{11}$, $t_{12}$, $t_{11}'$, $t_{12}'$, $t_{15}$, $t_{16}$ の内、固定局(14)と各静止衛星(12)及び(13)との間の伝送時間 $t_{12}$, $t_{12}'$, $t_{15}$ は距離から判断できる。そして、残りの伝送時間 $t_{11}$, $t_{11}'$, $t_{16}$ は、移動体(11)の位置により変化する。ここで、時間 $t_{11}$ と $t_{11}'$ とは同一距離の伝送なので同一時間であり、移動体(11)が測位開始信号を送信してから第1の静止衛星(12)からの第1の基準信号を受信するまでに要した時間 $t_a$ から、既知の時間 $t_{12}$, $t_{12}'$, $t_{13}$ を減算することで、伝送時間 $t_{11}$ ($t_{11}'$) が算出される。

また、移動体(11)が測位開始信号を送信してから第2の静止衛星(13)からの第2の基準信号を受信するまでに要した時間 $t_b$ から、既知の時間 $t_{12}$, $t_{14}$, $t_{15}$ と算出した時間 $t_{11}$ とを減算することで、伝送時間 $t_{16}$ が算出される。

このようにして伝送時間 $t_{11}$, $t_{16}$ が算出されると、伝送速度からこの時間情報 $t_{11}$, $t_{16}$ が距離情報に換算でき、移動体(11)と各静止衛星(12)及び(13)との距離が求まる。そして固定局(14)では、さらにこの2つの距離と各静止衛星(12)及び(13)の正確な位置情報に基づいて、移動体(11)の2次元的な位置を算出し、この算出した2次元的な位置情報と、固定局(14)が備える地勢図のデータベースを用いて、移動体(11)の3次元的な位置を算出する。このときの位置算出は、従来と同様

に行われる。また、この座標位置の算出を行う場合に、各サービスエリア内に位置校正用固定局（図示せず）を設け、固定局(14)と位置校正用固定局との間で、各静止衛星(12)及び(13)を介して信号の伝送を行い、返送される信号に基づいて検出した座標位置の校正を行い、より正確な測位を行うようにしても良い。

このように本例によると、移動体(11)から静止衛星を介した1回線の伝送と、固定局(14)から静止衛星を介した2回線の伝送とで、移動体(11)の測位ができる。このため、移動体(11)は静止衛星への送信装置として1回線分だけ装備すれば良く、移動体(11)が備える測位のための装置が小型化できる。特に、衛星への送信装置は送信アンテナ等の大型の装置が必要で、自動車のような小型の移動体(11)への測位装置の設置が少ないスペースで出来る。この場合、測位のための演算は固定局(14)側で行うので、測位の精度が落ちることはない。なお、移動体(11)が搭載する受信装置は、比較的大電力の信号を受信するので、送信装置に比べて小型に構成でき、2回線分の設置でもスペースを取らない。また、静止衛星自体も、移動体(11)からの比較的小電力の信号を中継するものは第1の静止衛星(12)だけで良く、第2の静止衛星(13)は固定局(14)からの大電力の信号を中継する機能だけで良く、第2の静止衛星(13)として汎用の通信衛星が使用でき、測位のための専用の衛星として第1の静止衛星(12)だけを用意すれば良い。

なお、上述実施例においては、トラック等の自動車の測位を行う伝送システムとしたが、船舶等他の移動体の測位を行う伝送システムにも適用できる。また、上述実施例に示した送信周波数は、一例を示したもので、使用条件に応じて各種周波数を選定すれば良い。さらにまた、本発明は上述実施例に限らず、その他種々の構成が取り得ることは勿論である。

〔発明の効果〕

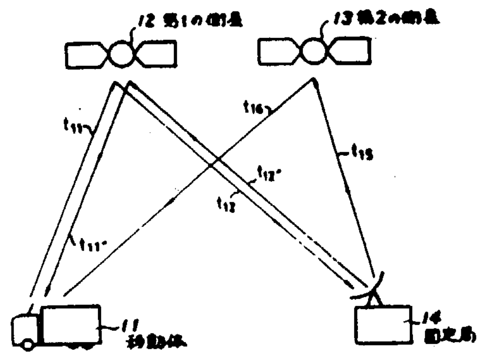
本発明によると、移動体側が1回線用の送信装置だけを搭載する簡単な構成で測位ができると共に、移動体側からの信号を中継する衛星も1個で良く、簡単な構成で正確な測位ができる。

図面の簡単な説明

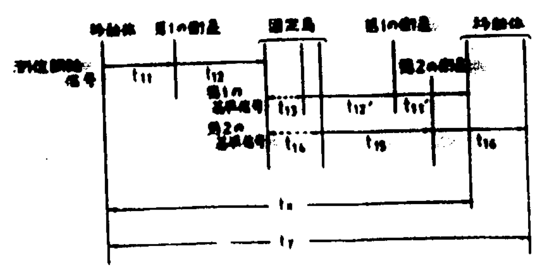
第1図は本発明の一実施例を示す構成図、第2図は一実施例の説明に供するタイミング図、第3図は従来例の構成図、第4図は従来例の説明に供するタイミング図、第5図は位置の算出状態の説明図である。

(11)は移動体、(12)は第1の静止衛星、(13)は第2の静止衛星、(14)は固定局である。

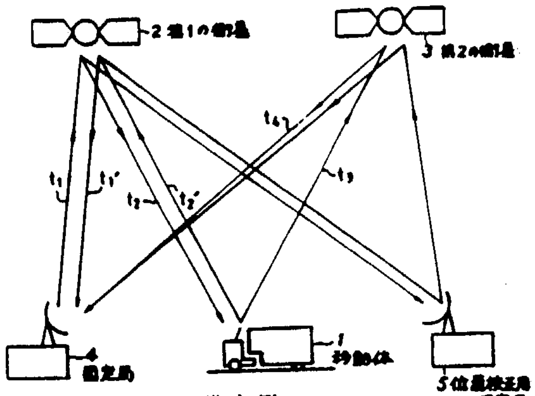
代理人　松隈秀盛



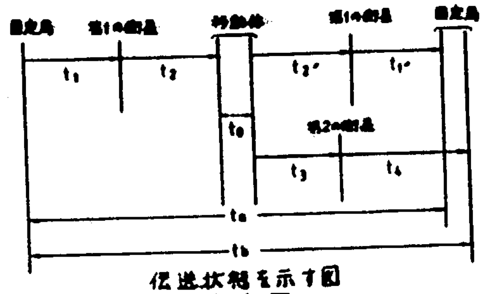
伝送システムの構成
第1図



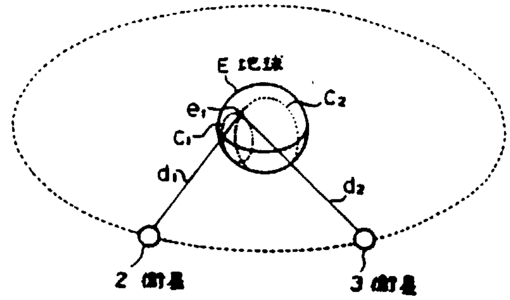
伝送状態を示す図
第2図




従来例
第3図




伝送状態を示す図
第4図




算出状態説明図
第5図

NET. 2

US005111209A

# United States Patent [19]

Toriyama

[11] Patent Number: 5,111,209

[45] Date of Patent: May 5, 1992

[54] SATELLITE-BASED POSITION DETERMINING SYSTEM

[75] Inventor: Ichiro Toriyama, Kanagawa, Japan

[73] Assignee: Sony Corporation, Tokyo, Japan

[21] Appl. No.: 703,202

[22] Filed: May 20, 1991

[30] Foreign Application Priority Data

May 23, 1990 [JP] Japan ................................ 2-133231

[51] Int. Cl.[5] ........................ H04B 7/185; G01S 5/02

[52] U.S. Cl. .................................. 342/357; 342/457; 364/449

[58] Field of Search ...................... 342/357, 457, 356; 364/449; 340/988, 991, 995

[56] References Cited

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4,918,609 4/1990 Yamawaki .......................... 364/449

5,017,926 5/1991 Ames et al. ......................... 342/357

*Primary Examiner*—Theodore M. Blum

*Attorney, Agent, or Firm*—Philip M. Shaw, Jr.

[57] ABSTRACT

Disclosed herein is a transmission system for determining a position of a mobile station by using communication satellites. The determination of the position of the mobile station is effected by one-line signal transmission from the mobile station through one satellite to a fixed station and by two-line signal transmission from the fixed station through two satellites to the mobile station. Thus, the construction of the transmission system can be made simple such that a transmitter for the one-line signal transmission needs to be mounted on the mobile station.

3 Claims, 5 Drawing Sheets

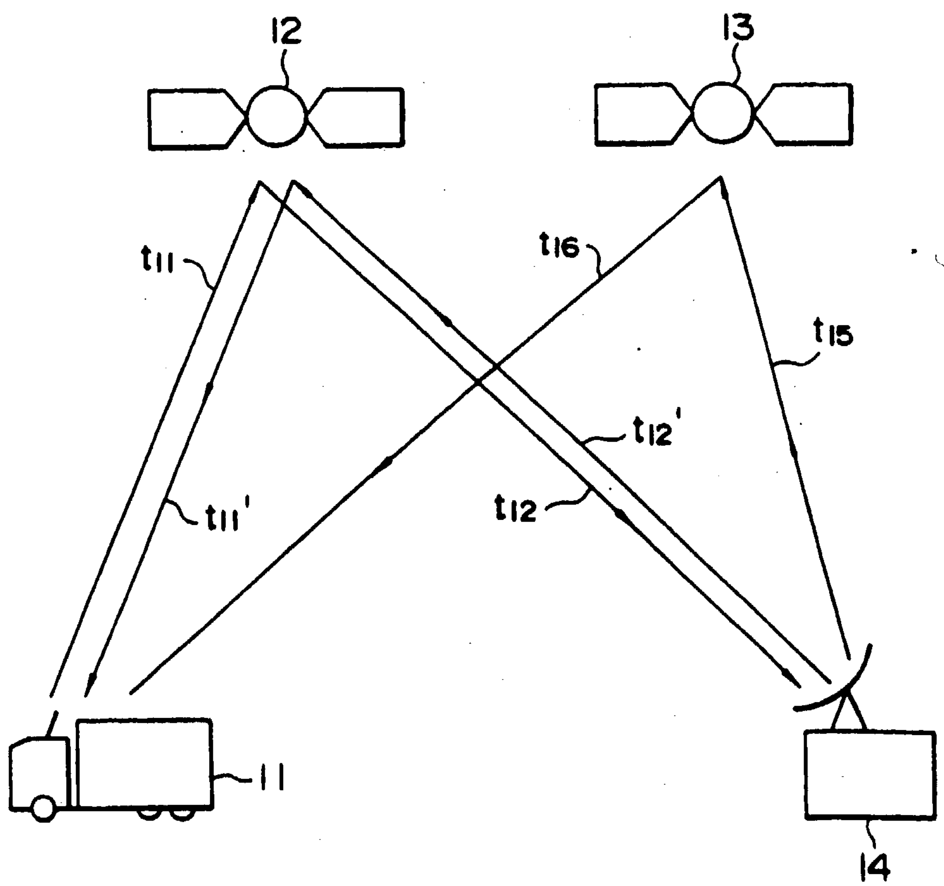


FIG. 1

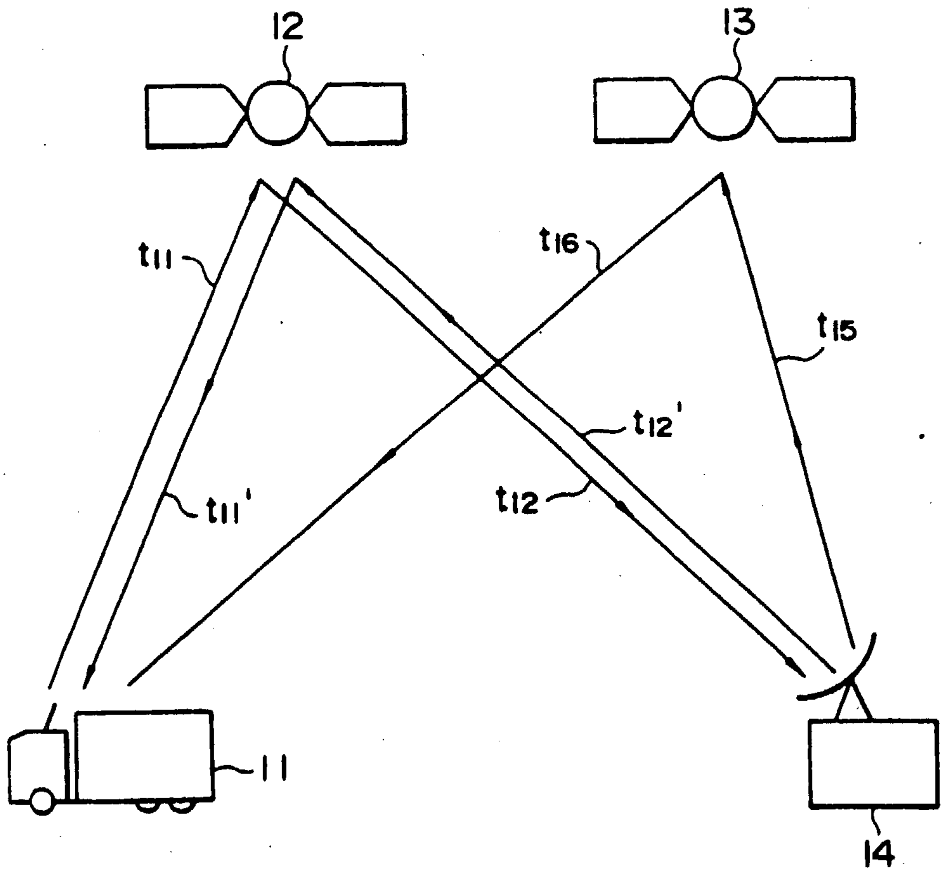
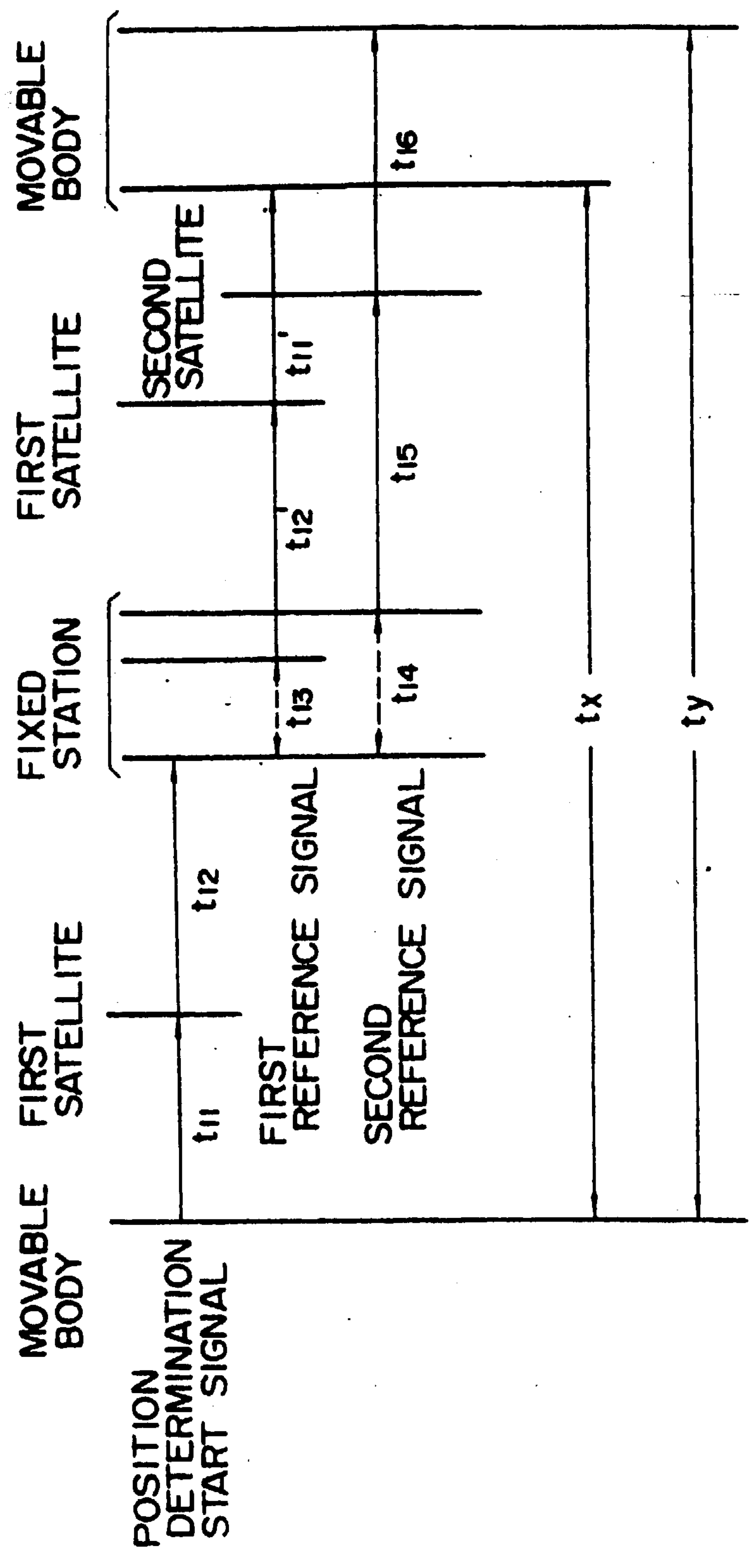


FIG. 2


MOVABLE BODY
FIRST SATELLITE
FIXED STATION
FIRST SATELLITE
SECOND SATELLITE
MOVABLE BODY
POSITION DETERMINATION START SIGNAL
FIRST REFERENCE SIGNAL
SECOND REFERENCE SIGNAL
$t_{11}$
$t_{12}$
$t_{13}$
$t_{14}$
$t_{12}$
$t_{11}'$
$t_{15}$
$t_{16}$
$t_x$
$t_y$

F I G. 3
PRIOR ART

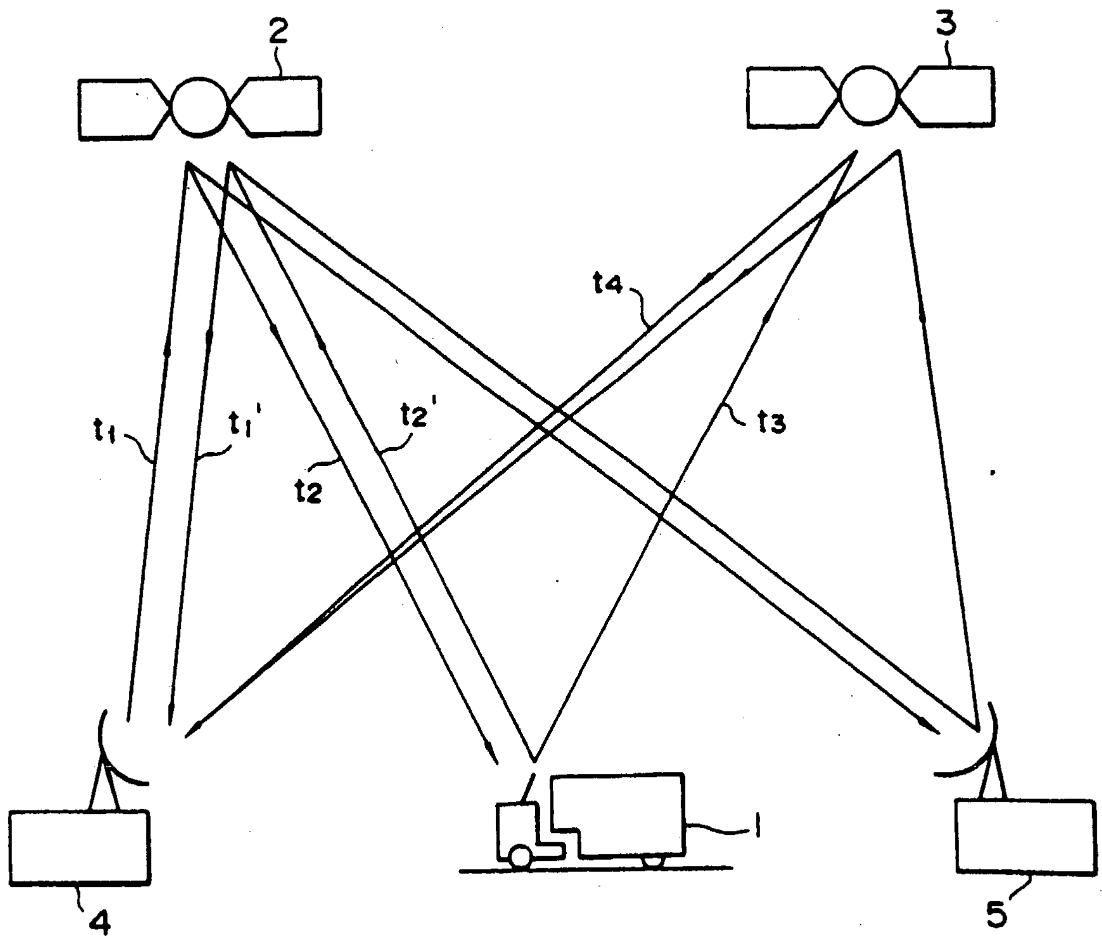
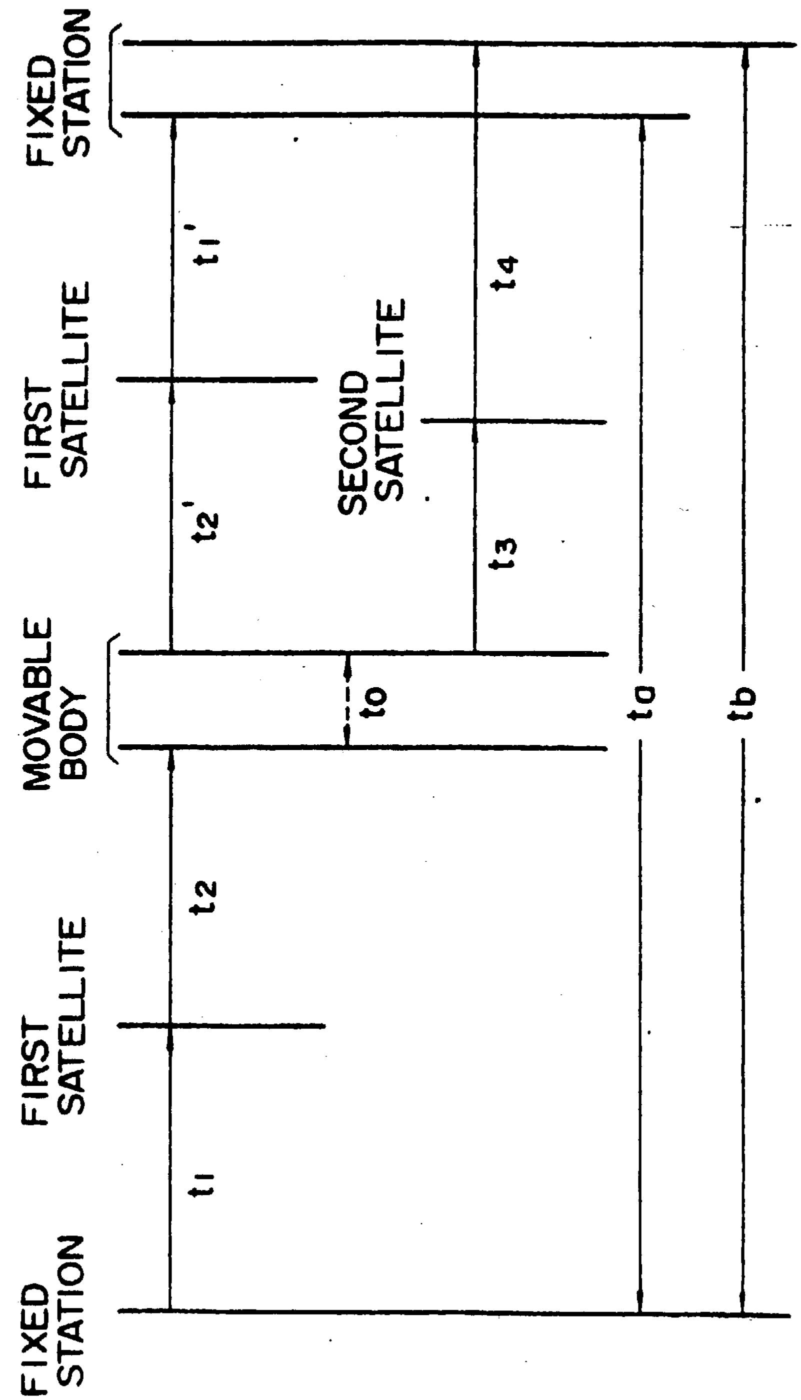
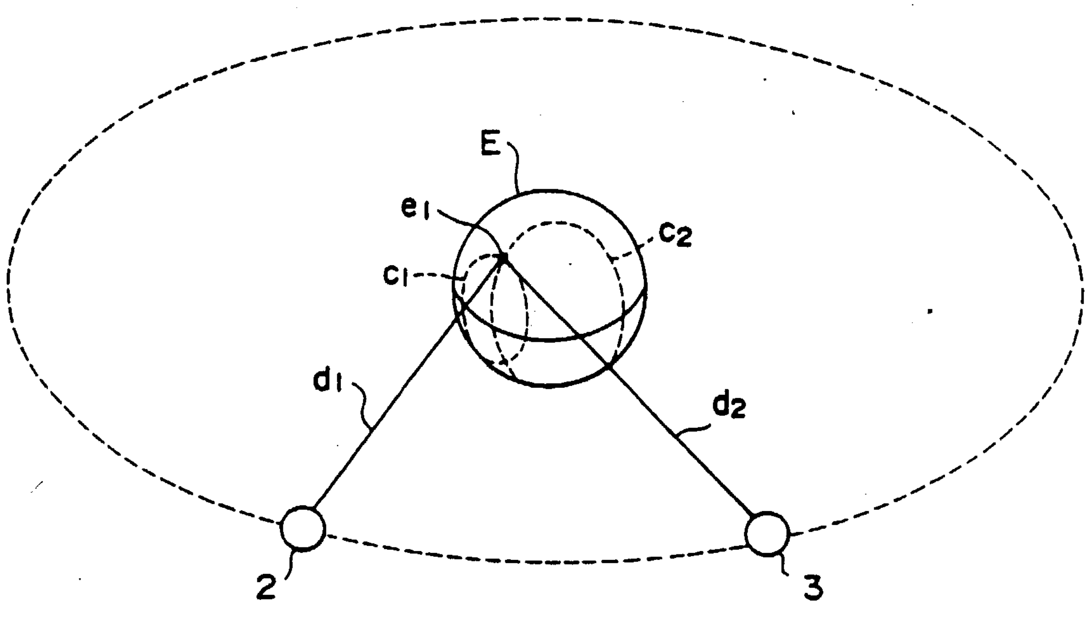


FIG. 4
PRIOR ART



F I G. 5



# SATELLITE-BASED POSITION DETERMINING SYSTEM

## BACKGROUND OF THE INVENTION

The present invention relates to a transmission system for determining a position of a mobile station by using communication satellites.

Conventionally, a position of a mobile station, which incorporated in a vehicle such as an automobile or a ship or an aircraft, is determined by using communication satellites. In the case of using three or more communication satellites, signals from these satellites are received by the mobile station. Then, on the basis of information obtained from receiving timings, a linear equation with four unknowns is solved to thereby calculate the position of the mobile station. This position determining system requires many satellites, and the mobile station requires to be equipped with a number of receivers corresponding to these satellites. Furthermore, it is necessary that precise computation for the position determination is to be carried out in the mobile station.

In contrast, there has been proposed in U.S. Pat. No. 4,839,656, for example, a position determining system employing two geostationary satellites and carrying out the computation for the position determination in a fixed station on the ground.

This known position determining system is constructed as illustrated in FIG. 3, for example. Referring to FIG. 3, reference numeral 1 designates a mobile station such as a truck whose present position is intended to be determined. The mobile station 1 is provided with a receiver for receiving a radio wave from a first geostationary satellite 2, a first transmitter for transmitting a radio wave to the first geostationary satellite 2, and a second transmitter for transmitting a radio wave to a second geostationary satellite 3. On the other hand, a fixed station 4 on the ground is provided with a transmitter for transmitting a radio wave to the first geostationary satellite 2, a first receiver for receiving a radio wave from the first geostationary satellite 2, and a second receiver for receiving a radio wave from the second geostationary satellite 3. Additionally, another fixed station 5 for calibrating the position of the mobile station 1 is located at a position remote from the fixed station 4. The position calibrating fixed station 5 is provided with a receiver for receiving a radio wave from the first geostationary satellite 2, a first transmitter for transmitting a radio wave to the first geostationary satellite 2, and a second transmitter for transmitting a radio wave to the second geostationary satellite 3.

Next, a procedure for determining a position of the mobile station 1 will be described with reference to FIG. 4. First, a synchronizing signal precisely managed in time is transmitted from the fixed station 4 to the first geostationary satellite 2. This synchronizing signal is relayed by the first geostationary satellite 2, and is then received by the receiver mounted on the mobile station 1. In regard to the transmission of the synchronizing signal from the fixed station 4 through the first geostationary satellite 2 to the mobile station 1, reference character $t_1$ denotes a time required for transmitting the synchronizing signal to the fixed station 4 to the first geostationary satellite 2, and reference character $t_2$ denotes a time required for transmitting the synchronizing signal from the first geostationary satellite 2 to the mobile station 1.



After a predetermined time $t_0$ has elapsed from a receiving timing of this synchronizing signal at the mobile station 1, a first packet signal containing an ID number of a terminal in the mobile station 1 and also containing information contained in an input signal is transmitted from the mobile station 1 to the first geostationary satellite 2. At the same time, i.e., after the predetermined time $t_0$ has elapsed from the receiving timing of this synchronizing signal, a second packet signal similar to the first packet signal is transmitted from the mobile station 1 to the second geostationary satellite 3. The above predetermined time $t_0$ is a constant value, and information of this time $t_0$ is preliminarily stored in the fixed station 4. In regard to the transmission of these packet signals from the mobile station 1 to the first and second geostationary satellites 2 and 3, reference character $t_2'$ denotes a time required for transmitting the first packet signal from the mobile station 1 to the first geostationary satellite 2, and reference character $t_3$ denotes a time required for transmitting the second packet signal from the mobile station 1 to the second geostationary satellite 3.

The first and second packet signals are relayed by the first geostationary satellite 2 and the second geostationary satellite 3, respectively, and are then received by the fixed station 4. In regard to the transmission of these packet signals from the first and second geostationary satellites 2 and 3 to the fixed station 4, reference character $t_1'$ denotes a time required for transmitting the first packet signal from the first geostationary satellite 2 to the fixed station 4, and reference character $t_4$ denotes a time required for transmitting the second packet signal from the second geostationary satellite 3 to the fixed station 4.

Thereafter, in the fixed station 4, a distance between the first geostationary satellite 2 and the mobile station 1 is calculated from a receiving timing of the first packet signal received from the first geostationary satellite 2, a transmitting timing of the synchronizing signal transmitted from the fixed station 4, and a distance between the fixed station 4 and the first geostationary satellite 2. Similarly, a distance between the second geostationary satellite 3 and the mobile station 1 is calculated from a receiving timing of the second packet signal received from the second geostationary satellite 3, the transmitting timing of the synchronizing signal, and a distance between the fixed station 4 and the second geostationary satellite 3. More specifically, the distance between the fixed station 4 and the first geostationary satellite 2 is a fixed value, and the distance between the fixed station 4 and the second geostationary satellite 3 is also a fixed value. Therefore, these distances can be preliminarily determined in the fixed station 4. Accordingly, the transmission time $t_1$ and the transmission time $t_1'$ between the fixed station 4 and the first geostationary satellite 2 can be determined from the above fixed distance between the fixed station 4 and the first geostationary satellite 2. Similarly, the transmission time $t_4$ between the fixed station 4 and the second geostationary satellite 3 can be determined from the above fixed distance between the fixed station 4 and the second geostationary satellite 3. In this case, the time $t_1$ is equal to the time $t_1'$ because the distance between the fixed station 4 and the first geostationary satellite 2 is fixed. The remaining transmission times $t_2$, $t_2'$ and $t_3$ varies with a position of the mobile station 1. As to the trans-

mission times $t_2$ and $t_2'$, since the transmission between the mobile station 1 and the first geostationary satellite 2 is carried out in the same distance, the transmission times $t_2$ and $t_2'$ are equal to each other. Accordingly, the transmission time $t_2$ ($=t_2'$) can be calculated by subtracting the known times $t_1$, $t_1'$ and $t_0$ from a total time $t_a$ required for the transmission from the transmitting timing of the synchronizing signal to the receiving timing of the packet signal via the first geostationary satellite 2. After thus determining the transmission time $t_2$, the transmission time $t_3$ can be calculated by subtracting the known times $t_1$, $t_2$, $t_4$ and $t_0$ from a total time $t_b$ required for the transmission from the transmitting timing of the synchronizing signal to the receiving timing of the second packet signal via the second geostationary satellite 3.

After thus calculating these transmission times $t_2$ and $t_3$, information of the times $t_2$ and $t_3$ is converted into information of distances on the basis of a transmission rate, thus obtaining the distance between the mobile station 1 and the first geostationary satellite 2 and the distance between the mobile station 1 and the second geostationary satellite 3. Then, on the basis of these two distances and information of precise positions of the first and second geostationary satellites 2 and 3, a two-dimensional position of the mobile station 1 is calculated in the fixed station 4.

Then, by using this two-dimensional position calculated above and a data base of a terrain map provided in the fixed station 4, a three-dimensional position of the mobile station 1 is calculated.

A manner of calculating the three-dimensional position of the mobile station 1 in the fixed station 4 will now be described with reference to FIG. 5. Referring to FIG. 5, reference character dl denotes a distance between the mobile station 1 and the first geostationary satellite 2 which exists on a predetermined orbit, and reference character $d_2$ denotes a distance between the mobile station 1 and the second geostationary satellite 3 which also exists on the above predetermined orbit. A point on the earth E remote from the first geostationary satellite 2 by the distance $d_1$ describes a circle $c_1$, and a point on the earth E remote from the second geostationary satellite 3 by the distance $d_2$ describes a circle $c_2$. Accordingly, two intersections $e_1$ between the circles $c_1$ and $c_2$ exist on the earth E, one of which intersections $e_1$ existing on the northern hemisphere, while the other existing on the southern hemisphere. A coordinate position of each intersection $e_1$ can be determined from the data base of the terrain map.

Further, in carrying out the calculation of the coordinate position of the mobile station 1, the transmission of signals may be carried out between the fixed station 4 and the position calibrating fixed station 5 in each service area via the first and second geostationary satellites 2 and 3, so as to calibrate the above calculated coordinate position according to the signal returned to the position calibrating fixed station 5.

In the above prior art transmission system for determining a position of the mobile station 1, it is necessary to carry out the two-line inbound transmission from the mobile station 1 to the fixed station 4 and the one-line outbound transmission from the fixed station 4 to the mobile station 1. That is, the mobile station 1 needs to have two sets of transmitters consisting of the first transmitter for transmitting a radio wave to the first geostationary satellite 2 and the second transmitter for transmitting a radio wave to the second geostationary satellite 3. In general, such a transmitter for transmitting a radio wave to a geostationary satellite requires a relatively large transmission antenna, for example. Accordingly, it is not easy to mount the two sets of transmitters on a relatively small mobile station such as an automobile. Further, this prior art transmission system requires two geostationary satellites for relaying relatively small power radio waves from the mobile station, causing an increase in cost for the construction of the system.

## SUMMARY OF THE INVENTION

It is accordingly an object of the present invention to provide a transmission system which can determine a position of a mobile station with a simple construction such that one-line signal transmission from the mobile station is needed.

According to the present invention, there is provided a transmission system for determining a position of a mobile station comprising means provided in said mobile station for transmitting a position determination signal from said mobile station through a first geostationary satellite to a fixed station; means provided in said fixed station for receiving said position determination signal; means provided in said fixed station for transmitting a first reference signal through said first geostationary satellite to said mobile station; means provided in said fixed station for transmitting a second reference signal through a second geostationary satellite to said mobile station; means provided in said mobile station for receiving said first reference signal; means provided in said mobile station for receiving said second reference signal; means provided in said mobile station for measuring a first period of time from a transmitting timing of said position determination signal to a receiving timing of said first reference signal and measuring a second period of time from the transmitting timing of said position determination signal to a receiving timing of said second reference signal; said transmitting means provided in said mobile station transmitting information of said first and second periods of time measured above through said first geostationary satellite to said fixed station; and means provided in said fixed station for computing the position of said mobile station according to the information of said first and second periods of time transmitted above.

With this construction, the determination of the position of the mobile station is effected by one-line signal transmission from the mobile station through one satellite to a fixed station and by two-line signal transmission from the fixed station through two satellites to the mobile station. Thus, the construction of the transmission system can be made simple such that a transmitter for the one-line signal transmission needs to be mounted on the mobile station. Furthermore, only one satellite for relaying the signal transmission from the mobile station to the fixed station is necessarily used to effectuate precise determination of the position with a simple construction.

Other objects and features of the invention will be more fully understood from the following detailed description and appended claims when taken with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of the construction of the transmission system according to a preferred embodiment of the present invention;

FIG. 2 is a timing chart for explaining the transmission of signals in the transmission system shown in FIG. 1;

FIG. 3 is a schematic illustration of the construction of the transmission system in the prior art;

FIG. 4 is a timing chart of explaining the transmission of signals in the transmission system shown in FIG. 3; and

FIG. 5 is a schematic illustration for explaining a manner of calculation of a position of a mobile station.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

There will now be described a preferred embodiment of the present invention with reference to FIGS. 1 and 2.

In this preferred embodiment, determination of a position of a mobile station is carried out by a transmission system as shown in FIG. 1. Referring to FIG. 1, reference numeral 11 designates a mobile station such as a truck whose position is to be determined. The mobile station 11 is provided with a first receiver for receiving a radio wave from a first geostationary satellite 12, a second receiver for receiving a radio wave from a second geostationary satellite 13, and a transmitter for transmitting a radio wave to the first geostationary satellite 12. In this case, the transmission from the mobile station 11 to the first geostationary satellite 12 is carried out with a frequency band of 1.6 GHz, for example, and the transmission from each of the first geostationary satellite 12 and the second geostationary satellite 13 to the mobile station 11 is carried out with a frequency band of 4 GHz, for example. Further, a fixed station 14 on the ground is provided with a first transmitter for transmitting a radio wave to the first geostationary satellite 12, a second transmitter for transmitting a radio wave to the second geostationary satellite 13, and a receiver for receiving a radio wave from the first geostationary satellite 12.

Next, a procedure for determining a position of the mobile station 11 will be described with reference to FIG. 2. First, when a present position of the mobile station 11 is intended to be determined, a position determination signal is transmitted from the mobile station 11 to the first geostationary satellite 12. At this time, a transmitting timing of the position determination signal is stored in the mobile station 11. In regard to this transmission, reference character $t_{11}$ denotes a time required for the transmission of the position determination signal from the mobile station 11 to the first geostationary satellite 12.

Then, the position determination signal relayed by the first geostationary satellite 12 is received by the receiver in the fixed station. In regard to this transmission, reference character $t_{12}$ denotes a time required for the transmission of the position determination signal from the first geostationary satellite 12 to the fixed station 14. When the position determination signal is received by the receiver in the fixed station 14 as mentioned above, a first reference signal containing a predetermined identification signal is transmitted from the first transmitter in the fixed station to the first geostationary satellite 12 after a predetermined time $t_{13}$ has elapsed. At the Same time, a second reference signal containing a predetermined identification signal is transmitted from the second transmitter in the fixed station 14 to the second geostationary satellite 13 after a predetermined time $t_{14}$ has elapsed. In regard to the transmission from the fixed station 14 to the first geostationary satellite 12 and the second geostationary satellite 13, reference character $t_{12}'$ denotes a time required for the transmission of the first reference signal from the fixed station 14 to the first geostationary satellite 12, and reference character $t_{15}$ denotes a time required for the transmission of the second reference signal from the fixed station 14.

Then, the first reference signal relayed by the first geostationary satellite 12 is received by the first receiver in the mobile station 11, while the second reference signal relayed by the second geostationary satellite 13 is received by the second receiver in the mobile station 11. In the mobile station 11, it is determined which of the first and second reference signals has been relayed by either the first geostationary satellite 12 or the second geostationary satellite 13 according to the identification signals contained in the reference signals received. In regard to the transmission from the first geostationary satellite 12 and the second geostationary satellite 13 to the mobile station 11, reference character $t_{11}'$ denotes a time required for the transmission of the first reference signal from the first geostationary satellite 12 to the mobile station 11, and reference character $t_{16}$ denotes a time required for the transmission of the second reference signal from the second geostationary satellite 13 to the mobile station 11.

As shown in FIG. 2, reference character $t_x$ denotes a total time required for the transmission from the transmitting timing when the position determination signal is transmitted from the mobile station 11 to a receiving timing when the first reference signal is received by the mobile station 11, while reference character $t_y$ denotes a total time required for the transmission from the transmitting timing when the position determination signal is transmitted from the mobile station 11 to a receiving timing when the second reference signal is received by the mobile station 11. Both the total time $t_x$ and the total time $t_y$ are measured by a measuring means in the mobile station 11.

In the next step, information of the total time $t_x$ and the total time $t_y$ measured above is transmitted from the mobile station 11 through the first geostationary satellite 12 to the fixed station 14. Subsequently, in the fixed station 14, a distance between the first geostationary satellite 12 and the mobile station 11 is calculated from the total time $t_x$, and a distance between the second geostationary satellite 13 and the mobile station 11 is calculated from the total time $t_y$. More specifically, a distance between the fixed station and the first geostationary satellite 12 is a fixed value, and a distance between the fixed station 14 and the second geostationary satellite 13 is also a fixed value. Therefore, these distances can be preliminarily determined in the fixed station 14. Accordingly, the transmission time $t_{12}$ and the transmission time $t_{12}'$ between the fixed station 14 and the first geostationary satellite 12 can be determined from the above fixed distance between the fixed station 14 and the first geostationary satellite 12. Similarly, the transmission time $t_{15}$ between the fixed station 14 and the second geostationary satellite 13 can be determined from the above fixed distance between the fixed station 14 and the second geostationary satellite 13. The remaining transmission times $t_{11}$, $t_{11}'$ and $t_{16}$ varies position of the mobile station 11. As to the transmission times $t_{11}$ and $t_{11}'$, since the transmission between the mobile station 11 and the first geostationary satellite 12 is carried out in the same distance, the transmission

times $t_{11}$ and $t_{11}$ are equal to each Other. Accordingly, the transmission time $t_{11}$ ($=t_{11}'$) can be calculated by subtracting the known times $t_{12}$, $t_{12}'$ and $t_{13}$ from the total time $t_x$.

Similarly, the transmission time $t_{16}$ can be calculated by subtracting the known times $t_{12}$, $t_{14}$ and $t_{15}$ and the above calculated time $t_{11}$ from the total time $t_y$.

After thus calculating the transmission times $t_{11}$ and $t_{16}$ is converted into information of distances on the basis of a transmission rate, thus obtaining the distance between the mobile station 11 and the first geostationary satellite 12 and the distance between the mobile station 11 and the second geostationary satellite 13. Then, on the basis of these two distances and information of precise positions of the first and second geostationary satellites 12 and 13, a two-dimensional position of the mobile station 11 is calculated in the fixed station 14. Then, by using information of this two-dimensional position calculated above and a data base of a terrain map provided in the fixed station 14, a three-dimensional position of the mobile station 11 is calculated. The calculation of the three-dimensional position of the mobile station 11 is carried out in the same manner as in the prior art. Further, in carrying out the calculation of the coordinate position of the mobile station 11, another fixed station for position calibration (not shown) may be provided in each service area, so as to carry out the transmission of signals between the fixed station 14 and the position calibrating fixed station via the first and second geostationary satellites 12 and 13 and calibrate the above calculated coordinate position according to the signal returned to the position calibrating fixed station, thereby more precisely determining the position.

According to the preferred embodiment as described above, the position of the mobile station 11 can be determined by the one-line transmission from the mobile station 11 via the first geostationary satellite 12 and the two-line transmission from the fixed station 14 via the second geostationary satellite 13. Accordingly, it is sufficient to have the mobile station 11 be equipped with a single transmitter for the one-line transmission via the first geostationary satellite 12, thereby making compact a position determining device to be equipped in the mobile station 11. In general, such a transmitter for the transmission to a geostationary satellite requires a large-sized transmission antenna. However, since a single transmitter is only necessary as the transmitter to be provided in the mobile station 11 according to the present invention, the position determining device can be installed in a small space as of an automobile as the mobile station 11. Further, since the computation for the position determination is carried out in the fixed station, the accuracy of the position determination is not lowered. Further, as the two receivers mounted on the mobile station 11 receive relatively large power signals, they can be made more compact than the transmitter, and an installation space for even the two receivers can be accordingly made small. Additionally, the first geostationary satellite 12 functions as a geostationary satellite for relaying a relatively small power signal from the mobile station 11, and the second geostationary satellite 13 functions only as a geostationary satellite for relaying a relatively large power signal from the fixed station 14. Accordingly, a general purpose communication satellite may be used as the second geostationary satellite 13, while the first geostationary satellite 12 is only necessary as a dedicated geostationary satellite for the purpose of the position determination.

Although the above preferred embodiment is applied to a transmission system for determining a position of an automobile such as a truck, the transmission system of the present invention may be applied to any other movable bodies such as a ship. Further, the transmission frequency as mentioned in the above preferred embodiment is merely exemplary, and it may be suitably selected according to a service condition.

While the invention has been described with reference to a specific embodiment, the description is illustrative and is not to be construed as limiting the scope of the invention. Various modifications and changes may occur to those skilled in the art without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A system for determining a position of a mobile station, comprising:

means incorporated in said mobile station for transmitting a position determination signal from said mobile station through a first geostationary satellite to a fixed station;

means incorporated in said fixed station for receiving said position determination signal;

means incorporated in said fixed station for transmitting a first reference signal through said first geostationary satellite to said mobile station;

means incorporated in said fixed station for transmitting a second reference signal through a second geostationary satellite to said mobile station;

means incorporated in said mobile station for receiving said first reference signal;

means incorporated in said mobile station for receiving said second reference signal;

means incorporated in said mobile station for measuring a first period of time from a transmitting timing of said position determination signal to a receiving timing of said first reference signal and measuring a second period of time from the transmitting timing of said position determination signal to a receiving timing of said second reference signal;

said transmitting means incorporated in said mobile station transmitting information of said first and second periods of time measured above through said first geostationary satellite to said fixed station; and

means incorporated in said fixed station for computing the position of said mobile station according to the information of said first and second periods of time transmitted above.

2. A method of determining a position of a mobile station, comprising the steps of:

transmitting a position determination signal from said mobile station through a first geostationary satellite to a fixed station;

receiving said position determination signal in said fixed station;

transmitting a first reference signal from said fixed station through said first geostationary satellite to said mobile station after a first predetermined time has elapsed from a receiving timing of said position determination signal;

transmitting a second reference signal from said fixed station through a second geostationary satellite to said mobile station after a second predetermined time has elapsed from the receiving timing of said position determination signal;

receiving said first reference signal in said mobile station;

receiving said second reference signal in said mobile station;

measuring a first period of time from a transmitting timing of said position determination signal to a receiving timing of said first reference signal and a second period of time from the transmitting timing of said position determination signal to a receiving timing of said second reference signal, in said mobile station;

transmitting information of said first and second periods of time measured above through said first geostationary satellite to said fixed station; and

computing the position of said mobile station according to the information of said first and second periods of time transmitted above, in said fixed station.

3. The transmission system as defined in claim 1, wherein said first reference signal contains a predetermined identification signal for identifying transmission through said first geostationary satellite, and said second reference signal contains a predetermined identification signal for identifying transmission through said second geostationary satellite.

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